ON THE ORIGIN AND METAMORPHOSES OF INSECTS

I.

The Classification of Insects

NOT many years ago the civil and ecclesiastical authorities of St. Fernando in Chili arrested a certain M. Renous on a charge of witchcraft, because he kept some caterpillars which turned into butterflies.* Most persons, however, are aware that the great majority of insects quit the egg in a state very different from that which they ultimately assume; and the general statement in works on entomology has been that the life of an insect may be divided into four periods. Thus, according to Kirby and Spence * "The states through which insects pass are four: the *egg*, the *larva*, the *pupa*, and the *imago*."

Burmeister,† again, says that, excluding certain very rare anomalies, "we may observe four distinct periods of existence in every insect, namely, those of the egg, the larva, the pupa, and the imago, or perfect insect." In fact, however, the various groups of insects differ very much from one another in the metamorphoses they pass through; in some, as in the grasshopper for instance, the changes consist principally in a gradual increase of size, and in the acquisition of wings; while others, as for instance the common fly, acquire their full bulk in a form very different from that which they ultimately assume, and pass through a period of inaction in which not only is the whole form of the body altered, not only are legs and wings acquired, but even the internal organs themselves, are almost entirely distintegrated and reformed. It will be my object to bring these changes clearly before you, and if possible to throw some light on the causes to which they are due, and on the indications they afford of the stages through which insects have been evolved.

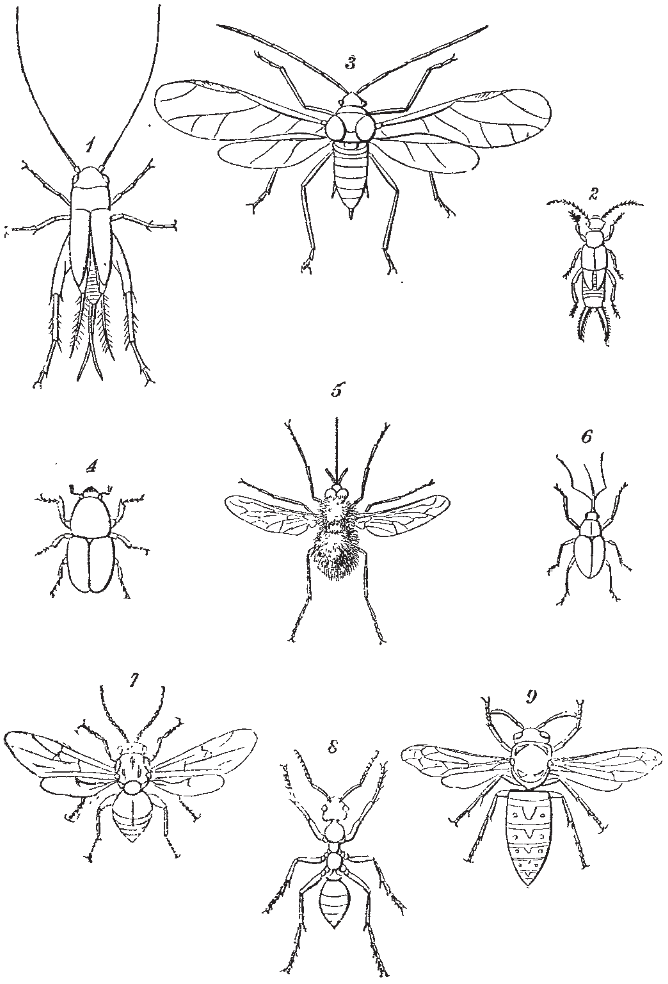

Plate 1

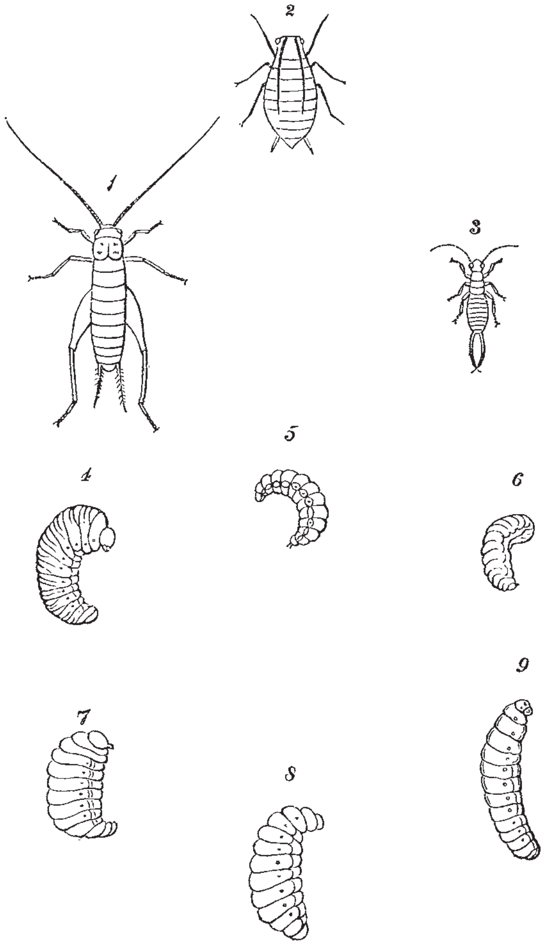

Plate 2

Pl. 1.‡—Fig. 1, Cricket. 2, Earwig. 3, Aphis. 4, Scolytus. 5, Anthrax. 6, Balaninus. 7, Cynips. 8, Ant. 9, Wasp (after Ormerod).
Pl. 2.—Fig. 1, Larva of Cricket. 2, Larva of Aphis. 3, Larva of Earwig. 4, Larva of Scolytus. 5, Larva of Anthrax. 6, Larva of Balaninus. 7, Larva of Cynips. 8, Larva of Ant. 9, Larva of Wasp.

The following list gives the orders or principal groups into which insects may be divided. I will not indeed, as this is not a work on the classification of insects, enter into my own views, but have adopted the system given by Mr. Westwood in his excellent "Introduction to the modern Classification of Insects," from which also, as a standard authority, most of the figures on Plates

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* Darwin's "Researches into the Geology and Natural History of the Countries visited by H.M.S. *Beagle*," p. 326.

* Introduction to Entomology vi. p. 50.

† Manual of Entomology, p. 30.

‡ When not otherwise acknowledged, the figures on the first four plates are principally borrowed from Mr. Whetwood's excellent "Introduction to the Modern Classification of Insects."

1 to 4, when not otherwise acknowledged, have been taken. He divides the insects into thirteen groups, with reference to eight of which it may be said that there is little difference of opinion among entomologists. These orders are by far the most numerous, and I have placed them in capital letters. With reference to the other five there is still much difference of opinion. It must also be observed that Prof. Westwood omits the parasitic Anoplura, as well as the Thysanura and Collembola.

Orders of Insects according to Westwood.

1.	HYMENOPTERA . .	Bees, Wasps, Ants, &c.
2.	Strepsiptera . . .	Stylops, Zenos, &c.
3.	COLEOPTERA . . .	Beetles.
4.	Euplexoptera . .	Earwigs.
5.	ORTHOPTERA . .	Grasshoppers, Crickets, Cockroaches, &c.
6.	Thysanoptera. . .	Thrips.
7.	NEUROPTERA . .	Ephemeras, &c.
8.	Trichoptera . . .	Phryganea.
9.	DIPTERA	Flies and Gnats.
10.	Aphaniptera . . .	Fleas.
11.	HETEROPTERA . .	Bugs.
12.	HOMOPTERA . .	Aphis, Coccus, &c.
13.	LEPIDOPTERA . .	Butterflies and moths.

Of these thirteen orders, the eight which I have placed in capital letters, namely the first, third, fifth, seventh, ninth, eleventh, twelfth, and thirteenth, are much the most important in the number and variety of species. The other five are comparatively small groups. The Strepsiptera are minute insects, parasitic on Hymenoptera. Rossi, by whom they were discovered, regarded them as Hymenopterous; Lamarck placed them among the Diptera; by others they have been considered to be most closely allied to the Coleoptera, but they are now generally treated as an independent order.

The Euplexoptera or Earwigs are only too familiar to most of us. Linnæus classed them among the Coleoptera, from which, however, they differ in their transformations. Fabricius, Olivier, and Latreille regarded them as Orthoptera, but Dr. Leach, on account of the structure of their wings, considered them as forming the type of a distinct order, in which view he has been followed by Westwood, Kirby, and many other entomologists.

The Thysanoptera, constituted of the Linnæan genus Thrips, minute insects well known to gardeners, differ from the Coleoptera in the nature of their metamorphoses, in which they resemble the Orthoptera and Hemiptera. The structure of the wings and mouthparts, however, are considered to exclude them from these two orders.

The Trichoptera, or Caddis worms, offer many points of resemblance to the Neuroptera, while in others they approach more nearly to the Lepidoptera. According to Westwood, the genus Phryganea "forms the connecting link between the Neuroptera and Lepidoptera."

The last of these small aberrant orders is that of the Aphaniptera, constituted of the family Pulicidæ. In their transformations, as in many other respects, they closely resemble the Diptera. Strauss Durckheim indeed said that "*la puce est un diptère sans ailes.*" Westwood, however, regards it as constituting a separate order.

As indicated by the names of these orders, the structure of the wings affords extremely natural and convenient characters, by which the various groups may be distinguished from one another. The mouth-parts also are very important; and, regarded from this point of view, the Insecta may be divided into two series—the Mandibulata and Haustellata, or mandibulate and suctorial groups, between which, as I have already shown,* the Collembola (Podura, Smynthurus, &c.), occupy an intermediate position. These two series would stand as follows :—

Mandibulata	*Haustellata*
Hymenoptera	Lepidoptera
Strepsiptera	Diptera
Coleoptera	Aphaniptera
Euplexoptera	Hemiptera
Orthoptera	Homoptera
Trichoptera ?	
Thysanoptera ?	

Again, and this is the most important from my present point of view, insects have sometimes been divided into two other series, according to the nature of the metamorphoses: Heteromorpha, to use the terminology of Prof. Westwood,* "or those in which there is no resemblance between the parent and the offspring and Homomorpha, or those in which the larva resembles the imago, except in the absence of wings. In the former the larva is generally worm-like and articulated in its form, of a soft and fleshy consistence, and furnished with a mouth, and often with six short legs attached in pairs to the three segments

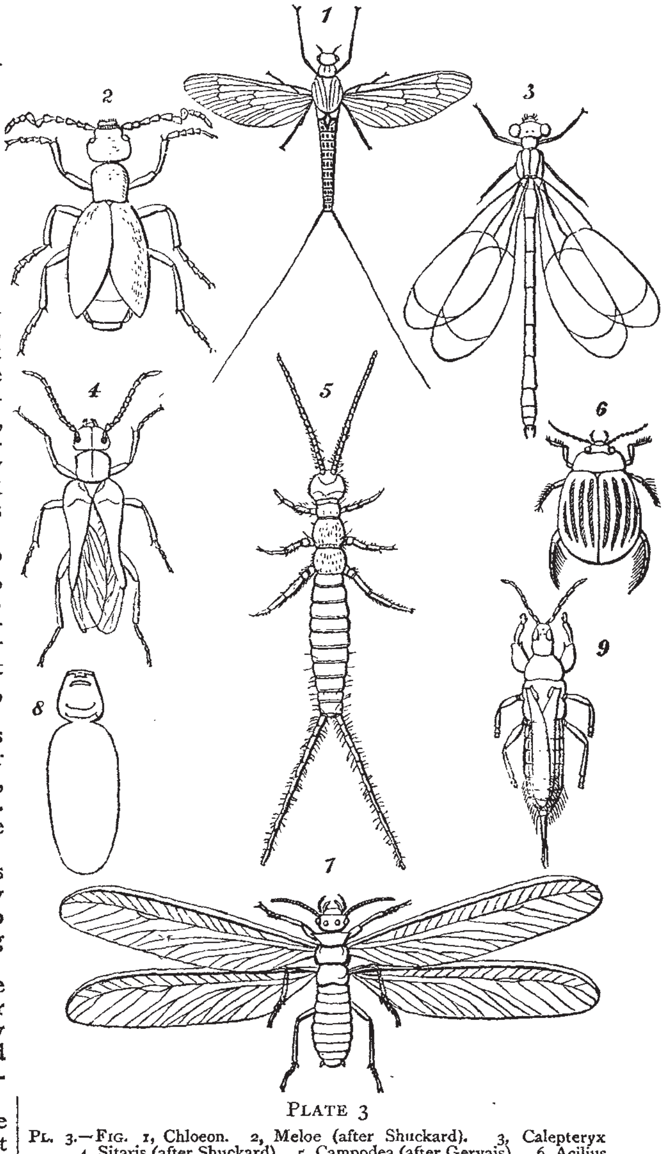

PLATE 3

PL. 3.—FIG. 1, Chloeon. 2, Meloe (after Shuckard). 3, Calepteryx 4, Sitaris (after Shuckard). 5, Campodea (after Gervais). 6, Acilius 7, Termes. 8, Stylops (female). 9, Thrips.

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* Linnæan Journal, vol. xi.

* Introduction to the modern Classification of Insects, p. 17.

succeeding the head. In the latter, including the Orthoptera, Hemiptera, Homoptera, and certain Neuroptera, the body, legs, and antennæ are nearly similar in their form to those of the perfect insect, but the wings are wanting."

Heteromorpha	*Homomorpha*
Hymenoptera	Euplexoptera
Strepsiptera	Orthoptera
Coleoptera	Hemiptera
Trichoptera	Homoptera
Diptera	Thysanoptera
Aphaniptera	
Lepidoptera	
Neuroptera	

But though the Homomorphic insects do not pass through such striking changes of form as those belonging to the other series, and are active throughout life, still it was until within the last few years generally (though erroneously) considered that in them, as in the Heteromorpha, the life fell into four distinct periods; those of (1) the egg, (2) the larva characterised by the absence of wings, (3) the pupa with imperfect wings, and (4) the imago or perfect insect.

I have, however, elsewhere * shown that there are not, as a matter of fact, four well-marked stages, and four only, but that in many cases the process is much more gradual.

The Hymenoptera are among the most interesting of insects. To this order belong the gallflies, the sawflies, the ichneumons, and above all, the ants and bees. We are accustomed to class the Anthropoid apes next to man in the scale of creation, but if we are to judge animals by their works, the chimpanzee and the gorilla must certainly give place to the bee and to the ant. The larvæ of the sawflies, which live on leaves, and of the Sirecidæ or long-tailed wasps, which feed on wood, are very much like caterpillars, having three pairs of legs, and in the former case abdominal prolegs as well; but in the great majority of Hymenoptera the larvæ are legless, fleshy grubs (Plate 2, Figs. 7-9); and the various modes by which the females provide for or secure them a sufficient supply of appropriate nourishment, constitutes one of the most interesting pages of Natural History.

The pupæ are inactive, and show distinctly all the limbs of the perfect insect, encased in distinct sheaths, and folded on the breast.

In the perfect state these insects are highly organised and very active. The working ants and some few species are wingless, but the great majority have four strong membranous wings, a character distinguishing them at once from the true flies, which have only one pair of wings. The species of Hymenoptera are very numerous; in this country alone there are about 3,000 kinds, most of which are very small.

The sawflies are so called because they possess at the end of the body a curious organ, corresponding to the sting of a wasp, but which is in the form of a fine-toothed saw. With this instrument the female sawfly cuts a slit in the stem or leaf of a plant, into which she introduces her egg.

The larva much resembles a caterpillar, both in form and habits. To this group belongs the nigger, or black caterpillar of the turnip, which is often in sufficient numbers to do much mischief. Some species of this group make galls, but the greater number of galls are formed by insects of another family, the Cynipidæ (Plate 1, Fig. 7). In this family the female is provided with an organ corresponding to the saw of the sawfly, but resembling a needle. With this she stings or punctures the surface of leaves, buds, stalks, or even roots of various plants. In the wound thus produced she lays one or more eggs. The effects of this proceeding, and particularly of the irritating fluid which she injects into the wound, is to produce a tumour or gall, within which the egg hatches, and on which the larva, a thick fleshy grub, (Plate 2, Fig. 7) feeds. In some species each gall contains a single larva; in others, several live together. The oak supports several kinds of gallflies; one forms the well-known oakapple, one forms a small swelling on the leaf resembling a currant, another produces a gall somewhat resembling an acorn, another attacks the root; the species making those bullet-like galls, which are now so common, has only existed for a few years in this country; the beautiful little spangles so common in autumn on the under side of oak-leaves are the work of another species, the *Cynips longipennis*. When the larva is full grown, it eats through the gall, falls to the earth, and turns into a chrysalis. One curious point about this group is, that in some of the commonest species the females alone are known, no one yet having ever succeeded in finding a male.

Another great group of the Hymenoptera is that of the ichneumons; the females lay their eggs either in or on other insects, within the bodies of which the larvæ live. They are thick, fleshy, legless grubs, and feed on the fatty tissues of their hosts, but do not attack the vital organs. When full grown, they eat their way through the skin of the insect, and turn into chrysalides. Almost every kind of insect is subject to the attacks of these horrid little creatures, which, however, are no doubt useful in preventing the too great multiplication of insects, and especially of caterpillars. Some species are so minute that they even lay their eggs within those of other insects. The larvæ of these genera assume very curious forms.

But of all Hymenoptera, the group containing the ant, the bee, and the wasp is the most interesting. This is especially the case with the social species, though the solitary ones also are extremely remarkable. The solitary bee or wasp, for instance, forms a cell generally in the ground, places in it a sufficient amount of food, lays an egg, and closes it up. In the case of bees, the food consists of honey; in that of wasps, the larva requires animal food, and the mother therefore places a certain number of insects in the cell, each species having its own special prey, some selecting small caterpillars, some beetles, some spiders. *Cerceris bupresticida*, as its name denotes, attacks beetles belonging to the genus Buprestis. Now if the Cerceris were to kill the beetle before placing it in the cell, it would decay, and the young larva when hatched would find only a mass of corruption. On the other hand, if the beetle were buried uninjured, in its struggles to escape it would be almost certain to destroy the egg. The wasp has, however, the curious instinct of stinging its prey just in the centre of the nervous system, thus depriving it of motion, and let us hope of suffering, but not killing it; when, therefore, the young larva leaves the egg, it finds ready a sufficient store of wholesome food. Other wasps, like the bees and ants, are social, and dwell together in communities. They live for one season, dying in autumn, except some of the females, which hybernate, awaking in the spring and forming new colonies. Even these, however, under ordinary circumstances, never live through a second winter. One specimen which I kept tame through last spring and summer, lived until the end of February, but then died. The larvæ of wasps are fat, fleshy, legless grubs. When they are full grown they spin for themselves a silken covering, within which they turn into chrysales. The oval bodies which are so numerous in ants' nests, and which are generally called ants' eggs, are really cocoons, not eggs. Ants are very fond of the honey-dew which is formed by the Aphides, and have been seen to tap the Aphides with their antennæ, as if to induce them to emit some of the sweet secretion. There is a species of Aphis, which lives on the roots of grass, and some ants collect these into their nests, keeping them, in fact, just as we do cows. One species of red ant does no work for itself, but makes slaves of a black kind, which then do everything for its masters.

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* Linnæan Transactions, 1863—"On the Development of Chloeon."

Ants also keep a variety of beetles and other insects in their nests. That they have some reason for this seems clear, because they readily attack any unwelcome intruder; but what that reason is we do not yet know. If these insects are to be regarded as the domestic animals of the ants, then we must admit that the ants possess more domestic animals than we do. But on this and many other points connected with ants we require additional information.

The Strepsiptera are a small, but very remarkable group of insects, parasitic on bees and wasps. The larva (Pl. 4, Fig. 8) is very minute, six-legged, and very active; it passes through its transformations within the body of the bee or wasp. The male and female are very dissimilar. The males are minute, very active, short-lived, and excitable, with one pair of very large membranous wings. The females (Pl. 3, Fig. 8), on the contrary, are almost motionless, and shaped very much like a bottle; they never quit the body of the bee, but only thrust out the head of the bottle between the abdominal rings of the bee.

JOHN LUBBOCK

(*To be continued.*)

*COTOPAXI—THE FIRST ASCENT OF THE GREAT VOLCANO**

STANDING fifty miles below the equator, and a hundred west of the meridian of Washington, Cotopaxi is at once the most beautiful and the most terrible of volcanoes. From the valley of Quito it appears like a huge truncated cone, in altitude equal to five Vesuviuses piled upon each other, its summit rising 4,000 ft. above the limit of perpetual snow, its sides presenting alternate ridges and gorges ploughed by descending floods of water, and around the base for miles heaps of ruins—boulders 20 ft. square, and volcanic ashes and mud 600 ft. deep. Very seldom does Cotopaxi wake up to intense activity, for as a rule the higher a volcano the less frequent its eruptions. Generally the only signs of life are the deep rumbling thunders and a cloud of smoke lazily issuing from the crater.

On November 27, 1872, Dr. Reiss—a German naturalist, who, with Dr. Stubel, has been exploring the Valley of Quito during the last forty years—set out from Mulolo with ten peones for the south-west point of the crater. Crossing the river Cutuche at Limpiopungo, where the stream cuts through vast deposits of volcanic ashes, he reached the "Ventanillas," a dry and sterile pampa, since the porous earth retains no moisture. Here the ascent of the cone began. Following the triangular ridge that divides the deep defiles of Manzanaguaico and Pucahuaico, and whose apex reaches the snow limit, he crossed subordinate cerros and pampas, which are so many steps in the grand staircase he was ascending. Vegetation now ceased entirely, and the surface was covered with ashes and black sand. In fact, nearly the whole occidental slope of Cotopaxi, between 12,500 and 16,000 ft., presents the aspect of a dismal black desert. Progress was slow, for at every step the foot sank into the sand, which increased in depth with the ascent.

Suddenly a profound chasm, containing fresh, smoking lava, was discovered on the left. This lava-stream was the lower limit of a vast mass, which from the valley appeared like a long black line. At 2 P.M. our traveller reached the point where the two quebradas unite, marked by an immense pile of rocks. Here he encamped for the night at an altitude of 15,179 feet.

An immense stream of lava came down the cone, and near the place of encampment divided, entering the two quebradas or ravines mentioned. The lava was still warm, clouds of vapour rising along the whole extent of the stream. During the afternoon the thermometer had stood at freezing point; but in the night it fell to twenty-five degrees.

The next day Dr. Reiss attained all his hopes. Cropping out of the lava stream, but mainly disposed along the borders of it, were numerous rough stones, upon which he advanced as on the rounds of a ladder. The greatest width of the lava current before it divided was about 3,000 ft., and the estimated thickness 150 ft. The lava was entirely black and warm in all its course; its temperature being from 68° to 91°, while that of the atmosphere was 32°. This elevated temperature explains the absence of snow on this part of the slope. The gaseous exhalations from the crevices seemed to be nothing more than air mixed with vapour. This is doubtless the lava-stream which flowed in 1854, and which, by melting vast quantities of snow, caused much devastation in the valley by floods. No fissure or accumulation of scoriæ indicates the source of the lava-stream; but the altitude of the point of departure is 18,700 feet.

At 8.45 he reached the arenal, a deep mass of fine sand stretching upward at an angle of 40°. Over this he must advance, difficult as it was, for on either side were impassable fields of snow and ice. The temperature of the sand was 77°. Another stream of lava was discovered, which must have flowed with great velocity, since, instead of following the inclination of the cone, it had descended diagonally. Only the peaks of Iliniza and Chimborazo in the opposite Cordillera were visible; but above the clouds, towards the south-west, a dense mass of smoke rose perpendicularly to a prodigious height, and then by an east wind was carried off in a horizontal line westward. This came from the furious and ever-active volcano of Sangay, whose top was invisible, but whose activity was manifested in this manner. As the clouds shifted, the diversified valley and its royal mountains were spread out like a map.

It was now 10.15 A.M.; thermometer, 28°. Fumeroles abounded, giving forth sulphurous gas. And now followed a sheet of compact blue ice, inclined from 35° to 40°; but fortunately it was not smooth, but covered with myriads of points or icicles three or four inches high. Scrambling over this, and climbing over and between walls, some of immense size, suddenly Dr. Reiss reached the edge of the crater. He had reached the western part of the southern lip. The crater presented an elliptical form, the major axis lying north and south. The stones which were continually falling in from all sides, but especially from the west side, rolled together as to the bottom of a funnel; there were no signs of a level bottom. The depth, roughly estimated, appeared to be 1,500 ft. The side of the funnel least inclined, and by which alone it is possible to descend, is the south-west; but here are large fumeroles sending forth dense masses of vapour charged with gas, and having a temperature of 156°. Around these fumeroles were masses of sulphur and a deposit of gypsum mixed with chloride of lime. This is of great interest as being the first instance of a chloride being found among the products of the South American volcanoes. Humboldt thought that the absence of hydrochloric acid was a characteristic of the New World volcanoes. The barometer gave 19,660 ft. as the altitude, while the doctor's trigonometrical observations, repeated at various times from independent bases in the valley, had given him 19,496 ft. as the height of the north peak, and 19,427 ft. for the southern. Both results exceed the altitude estimated by other travellers. Humboldt made it 18,880 ft.

Dr. Reiss left the crater at 1.45 P.M., and reached his encampment at the head of the ridge in three hours and a half, just as a heavy snow-storm began. He says he felt no inconvenience from the rarefaction of the air.

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* Abstract of an article by Mr. James Orton in the New York *Evening Post*, March 12, 1873.